Review of wetland inventory information in North America

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This report is considered a 'living' document and serves as the basis for updating and adding new information as it becomes available.

1 Introduction

The North American Region covers Canada, Mexico and the United States (U.S.) including Hawaii, Alaska, Puerto Rico, U.S. Virgin Islands, and the Samoan Islands (figure 1). The area encompasses approximately 2 029 626 km5 (World Resources Institute 1992) with a diversity of ecosystems extending from the Arctic to the tropics, and below sea-level to heights in excess of 6000 metres. The North American continent is bordered by four major bodies of salt water: the Caribbean, the Atlantic, Pacific and Arctic Oceans. A west coast mountain range extends from Alaska southward to the Mexico-Guatemala border. Several large river basins cover much of the continent and include the Mississippi, Saint Lawrence, MacKenzie, Rio Grande, Usamacinta, Fraser, Colombia and Colorado Rivers. Five great lakes in the interior of the continent – Superior, Michigan, Huron, Ontario and Erie – have a significant influence on the hydro-regimes. Much of Canada and northern United States experience temperatures below 0˚C causing most bodies of water to freeze for periods of up to six months in the extreme north. This has a significant effect on wetlands and their functions.

The following report summarises and analyses existing wetland data as part of a global effort to assess wetland inventories. There are eight sections to this report including references and annexes which contain valuable information summarised from existing reports. Recommendations based on the analysis are presented in the final section of this report.

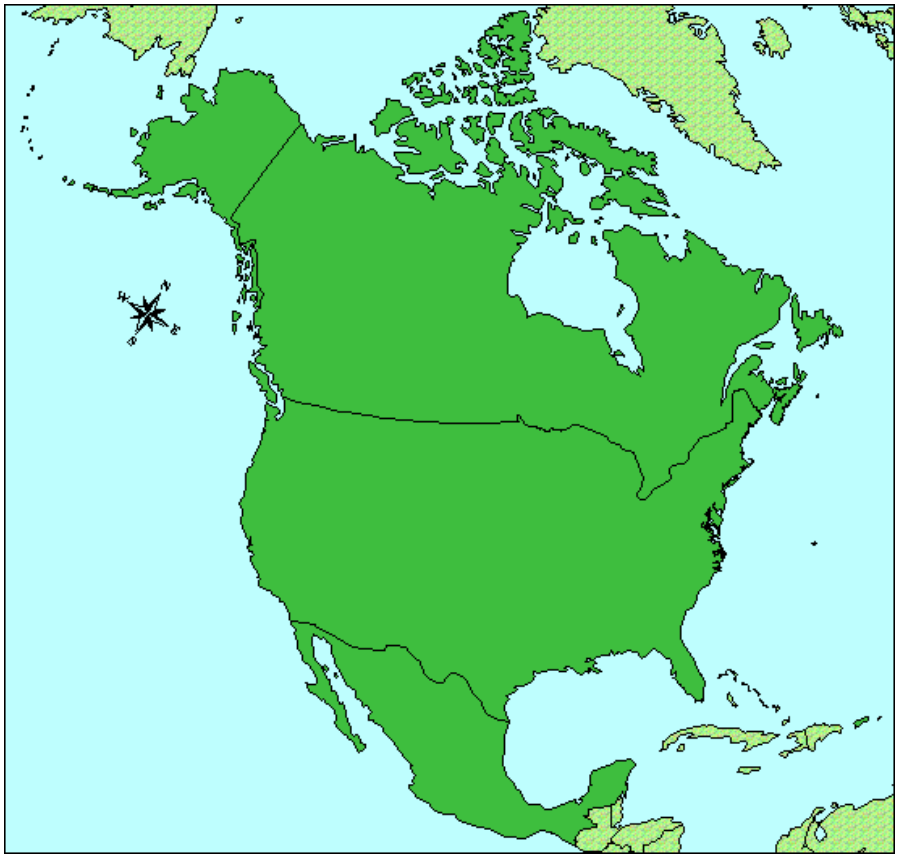

Figure 1 The North American region

2 Information sources

2.1 Methods used to obtain wetland inventory information

A variety of sources were consulted to determine the most up-to-date and reliable information on the extent, value and status of North America's wetlands. Information for the United States and Canada was readily available from natural resource agency libraries in Washington and Ottawa. Information for Mexico, however, was extremely difficult to obtain due to lack of data and a central clearinghouse mechanism to access information.

In Canada, the wetland office of the Canadian Wildlife Service (CWS) provided extensive information that was used as a baseline for collating additional resources in the country. In the United States, the National Wetland Inventory office of the United States Fish and Wildlife Service (USFWS) provided significant support in identifying relevant information, much of it now available on the Internet. In Mexico, Wetlands International's office and Secretaria de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP), provided valuable data sets. However, without a national or even state wetland inventories, it was extremely difficult to secure reliable data.

In summary, wetland information was gathered from:

- Wetlands International's library
- Other libraries
- Internet
- Contact with government representatives responsible for wetlands
- Questionnaires

Only a small portion of the total information collected was used in the analysis for this report. A significant proportion of the available information was already synthesised into comprehensive summaries. To select relevant information, an effort was made to use only that information at the state, province, territorial, national or multinational level. In the case of North America, it was felt that states and provinces were significantly large to justify including data from these areas.

2.2 Summary of information reviewed

Over 150 discrete sources of information were reviewed. Of these 29 were selected as sufficient to provide the necessary coverage for this report. Additional inventories reviewed but not included are listed in Appendix A.

For the United States, information on wetlands is summarised on a state by state basis for nearly each of the 50 states. The United States Fish and Wildlife Service has undertaken to complete a national wetland inventory which provides state by state information on wetland description, types, function, value, distribution, form, jurisdiction and conservation (to mention just a few categories).

A similar national wetland inventory does not exist for Canada. However, regional and provincial inventories exist for most areas, although the territories lack this data. Canada's immense area, its relative remoteness and extensive coverage of wetlands has made it nearly impossible to map the northern wetlands to date.

Information on wetlands in Mexico is lacking. Most of the information was gleaned from reports on discrete wetland regions, although some inventories have been carried out by Wetlands International, Ducks Unlimited Mexico (DUMAC), Conservation International (CI) and the USFWS.

Ramsar National reports were reviewed but provided very little information on inventories.

Table 1 is a summary of the documents included in this report. Although not exhaustive, the information contained within these documents provides a good overview of the results from wetland inventories carried out over the last two decades. Much of this information was collected in the last five years and is relatively current.

Table 1 Wetland inventory documents used in the analysis for the North American Region

Ontario Wetland Map Summary
Wetlands of the Maritime Provinces
National Topographic Data Base – Canada
Canadian Peat Harvesting and the Environment
Peatlands of Canada
Land Use Change on Wetlands in Southern Canada: Review and Bibliography
Soil Landscapes of Canada
Sensitive Ecosystems Inventory of East Vancouver Island and Gulf Islands
Wetland Distribution and Conversion in Southern Ontario
Canada's Wetlands – Maps of Wetland Regions and Distribution in Canada
Wetlands of Canada: Wetlands of International Importance (Ramsar)
Habitat Inventory Program
National Heritage Information Centre
Alberta's Wetlands: Water in the Bank!
Wetlands of the St Lawrence River Region 1950–1978
Wetlands of the Fraser Lowland : An Inventory
Wetlands: Red Para La Conservacion de Los Humedales, Mexico
Boletin Humedales de Mexico
Guia Regional para el Conocimiento, Manejo y Utilizacion de Humedales del Noroeste de Mexico
National Water Summary on Wetland Resources
A User's Guide to the Wisconsin Wetland Inventory (for information on available data)
Summary Report 1992 National Resources Inventory
National Water Summary on Wetland Resources
Wetlands of the United States: Current Status and Recent Trends
Status and Trends of Wetlands and Deepwater Habitats in the Conterminous U.S. 1950s to 1970s
Wetlands Status and Trends in the Conterminous United States: Mid-1970s to mid-1980s
Wetlands of the United States
National Wetlands Inventory Database
A Directory of Neotropical Wetlands

Table 2 Attributes of the wetland inventory documentation

Attribute	Analysis (n = 29)
Inventory type:	14 national (6 Canada, 2 Mexico, 6 U.S.) 15 sub-national (10 Canada, 1 Mexico, 4 U.S.)
Publication date:	oldest: 1983 newest: 1998 period: 7 (1980–89); 22 (1990–99)
Coverage:	each country is covered and in the U.S. almost every state is inventoried and mapped
Language:	almost entirely in English except for data from the province of Quebec, Canada
Publication format:	mixture of publications, maps, databases, World Wide Web based
Inventory format:	32% wetland directories
Implementation agencies:	71% government, remaining by sub-regional governments and international, national and sub-regional NGOs
Funding sponsor:	71% funded by national governments, remaining funded by sub-regional governments and international, national and sub-regional NGOs

3 Extent and adequacy of wetland inventory information

3.1 Objectives

The objectives of a wetland inventory can vary depending on the type of information required. Wetland inventories are compiled for various reasons including: to determine wetland status; to provide background information for future monitoring; and to identify important habitats for wildlife, economic interests and other functions.

Inventories included in this report are divided into four categories based on their objectives and include:

1. General wetland inventories
2. Inventories of wetland sites of international importance
3. Wetland type inventories
4. Other inventories

General wetland inventories

The first category describes inventories with the common objective of identifying wetland location, extent and type. In the United States, the National Wetland Inventory (NWI) Office inventories wetlands on a state by state basis and, although it is thorough in its coverage, does not secure the level of detailed information achieved through site inventories such as the *Directory of Neotropical Wetlands* (Scott & Carbonell 1986). Instead, the NWI maps delineate wetland areas and identify wetland types using Cowardin et al's (1979) classification system (refer to Appendix B). The NWI provides standard map products including more than 50 800 maps covering 88% of the conterminous United States, 30% of Alaska and all of Hawaii and the U.S. Territories. Current mapping efforts use a scale of either 1:24 000 or 1:63 360 (Alaska). The NWI is also

preparing a geographically digital database for wetlands so that wetland information can be placed into geographic information systems for use with computers.

To date, almost 18 800 maps representing 29% of the United States have been digitised. Statewide databases have been digitised for Delaware, Hawaii, Indiana, Illinois, Iowa, Maryland, Minnesota, New Jersey, Washington and West Virginia. Digitisation is in progress for Florida, North Carolina, South Carolina, South Dakota and Virginia. Wetland digital data are available for parts of 35 other states (Fretwell et al 1996).

The Coastal Wetland Habitat Program of the U.S. National Oceanic and Atmospheric Administration (NOAA) provides data on coastal wetland habitats and adjacent uplands to monitor changes in these habitats. The database contains excellent data on aerial extent and distribution of coastal wetlands in conterminous United States and serves as a basis for comparative temporal studies.

The USDA National Resources Inventory (NRCS 1995) is the most comprehensive database ever assembled on natural resources on non-federal lands of the United States – 74% of the nation's land area (refer to USDA Natural Resources Conservation Service Website). Data on acreage for marine, estuarine, riverine, lacustrine and palustrine habitat systems is presented. It is assumed that much of this data comes from soil type maps.

The U.S. Geological Survey produced the *National Water Summary on Wetland Resources* (Fretwell et al 1996*)*. This extremely comprehensive study on wetlands provides an overview of the current state of wetlands including a state-by-state summary of wetland extent and loss.

The National Oceanic and Atmosphere Administration (NOAA) oversees a major coastal habitat monitoring project and has inventoried most of coastal United States including its wetlands.

The Canadian government published a map of wetland regions in 1986 (Environment Canada 1986). These wetland ecoregions were defined as areas within which similar characteristic wetlands develop in locations that have a similar topography, hydrology and nutrient regime. Subdivisions of the wetland ecoregions were made based on the distribution of these wetlands, the relative abundance of the various kinds of wetlands, or development trends somewhat divergent to those in the rest of the region. For each region, wetland types were defined as bog, marsh, fen, swamp and shallow water (Canadian Energy Mines and Resources 1986a). Five regions are recognised: Arctic, Boreal, Prairie, Mountain and Oceanic. Regions are further subdivided into 20 sub-regions which in turn are further subdivided into another 28 'micro' sub-regions. This inventory does not identify specific wetlands, rather it delineates wetland regions within which one would expect to find wetlands with similar wetland characteristics. Wetland inventories for regions defined by watersheds (eg the Great Lakes), ecological boundaries (eg the prairie region) and by political boundaries (eg provincial or territorial borders) also exist. However, each has been designed to meet the needs of the primary user. As such, a national standard has not been widely accepted and makes for difficult analyses. A list of selected initiatives are included in Appendix A**.**

In Mexico, the objectives of the few wetland inventories that exist are site based rather than national in scope.

Inventories of wetland sites of international importance

A second category includes important site inventories. The objectives of these inventories are primarily based on specific characteristics of a site which confer upon it an international recognition. This is usually based on biodiversity characteristics, eg breeding grounds for birds or nurseries for fish. Inventories of important wetland sites, particularly those of international importance in Canada, are coordinated through the CWS, however, most site inventories are managed by provincial government and non-governmental organisations (NGOs) like Ducks Unlimited. The United States government has invested significant resources to determine the extent of wetlands through a National Wetland Inventory (NWI) project coordinated by the USFWS. However, the NWI does not exclusively identify internationally important wetland sites. A detailed regional inventory was completed for northwestern Mexico and analyses the status of each coastal wetland (Cervantes 1994).

In Mexico, priority wetlands were identified by SEMARNAP in 1994 and serve as the most comprehensive inventory of wetland sites at a national scale. This effort is being evaluated and a system using watersheds to define wetland regions is under completion (H Berlanga, SEMARNAP, pers comm 1999).

Important wetland sites for staging and breeding waterbirds have also been identified and inventoried in Canada, United States and, to some degree, Mexico through the efforts of the North American Waterfowl Management Plan (NAWMP) and the Western Hemisphere Shorebird Reserve Network (WHSRN). A GIS mapping inventory of wetlands of importance to migratory waterbirds for much of Mexico's Caribbean coast (not including the Yucatan) is being completed by Ducks Unlimited Mexico (DUMAC). These data have not been published but are available upon request.

Ramsar databases have been published for Canada and the United States and provide basic information on each internationally important site (Gillespie et al 1991).

Wetland type inventories

A third category of inventories focuses on specific wetland types such as peatlands, forested wetlands, coral reefs, flood plains, mangroves and estuarine habitat. A major initiative to map and inventory Canadian peatlands was recently completed by Tarnocai and Labelle (in development) and provides detailed information on peatland distribution and maps dominant peatland types at a national scale. A review of peatlands was also published by the North American Wetland Conservation Council–Canada (Keys 1992) and provides valuable information on peatland extent for each Canadian province and territory. An ongoing review on the extent and condition of United States coral reefs provides useful information on sites in both southern United States, the Caribbean and Polynesia (NOAA 1998). Large areas of prairie pothole regions of central United States and Canada have been mapped by Ducks Unlimited.

Other inventories

A fourth category combines various other natural resource inventories whose objectives in part include obtaining information on wetlands. In Canada, the National Topographic Data Base (NRCAN 1998) provides specific reference to 'water saturated soils'. This includes areas of wetlands, tundra and bog. Most of Canada has been mapped at a scale of 1:250 000 while maps at 1:50 000 exist for most of the southern and more populated regions. The State of Canada's Environment (Environment Canada 1991) provides a status report on wetlands of Canada but the

initiative was discontinued in the mid-nineties. The USDA Forest Service has completed detailed maps of forested habitat including lowland, flooded wetlands.

3.2 Wetland definition and classification

3.2.1 Wetland definition

Wetland definitions vary significantly within and among the three countries. In the United States, Cowardin et al's (1979) wetland classification system is widely used and defines wetlands as:

> lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: 1) at least periodically the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soils; and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

In general terms, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on the surface. Although there are many other definitions in use in the United States, this definition has become the standard of the NWI and those who use its data.

In Canada, the National Wetland Working Group (NWWG 1988) definition states:

> A wetland is defined as land that has the water table at, near or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment.

In many cases, this definition has been adopted and slightly modified to meet the requirements of other specific inventories. However, a number of researchers developed their own definition and classification of wetlands making a comparison of inventory data difficult. Lynch-Stewart and Rubec (1995) concluded that compatibility of 18 major Canadian wetland databases was limited by the use of different classification systems.

In Mexico, the Ramsar Convention's definition of wetlands is used in most publications referring to wetlands. Ramsar defines wetlands as:

> areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

For various reasons, Ramsar's definition is not widely used in Canada or the United States. This may be due to its lack of profile up until the early 1990s, and also a regulatory need in the United States to establish a more concrete operational definition. With the advent of a 'no net loss of wetlands' policy, it was necessary to develop a well defined wetland classification system in order to properly define, delineate and monitor wetlands.

3.2.2 Classification systems

The purpose of a wetland classification system is to group like elements into units that can be defined and characterised. Wetland classifications were used in all of the national wetland inventories. Numerous classification systems have been developed and are in use particularly at the regional, state, provincial or thematic level. These are not discussed in this report. The

following information summarises those classification systems currently used to inventory wetlands at a national level.

Cowardin et al's classification system is widely used in the United States and serves as the basis for the NWI. The structure of this classification is hierarchical, progressing from Systems and Subsystems, and Dominance Types. Modifiers for regime, water chemistry and soils are applied to Classes, Subclasses and Dominance Types (named for the dominant plant or animal forms). Special modifiers describe wetlands and deepwater habitats that have been either created or highly modified by man or beavers.

Five major systems are recognised by Cowardin et al (1979):

- Marine (two Subsystems: Subtidal and Intertidal)
- Estuarine (two Subsystems: Subtidal and Intertidal)
- Riverine (four Subsystems: Tidal, Lower Perennial, Upper Perennial and Intermittent)
- Lacustrine (two Subsystems: Littoral and Limnetic)
- Palustrine (no Subsystem)

A widely used wetland classification system does not exist in Canada. However, the National Wetland Working Group (NWWG) proposed a national system to classify wetlands in Canada that builds on systems already established in the United States and Europe.

The Canadian Wetland Classification System (CWCS) contains three hierarchical levels: 1) class, 2) form, and 3) type. Five wetland classes are recognised on the basis of overall genetic origin of wetland ecosystems. Seventy wetland forms are differentiated on the basis of surface morphology of underlying mineral soil. Wetland types are classified according to vegetation physiognomy. The five wetland classes are:

- bog
- fen
- marsh
- swamp
- shallow water

Ramsar's wetland classification system (Ramsar Bureau 1998b) has not been adapted to North America. A generally accepted classification system for North America is unlikely. The United States classification system is widely in use but is of limited value in Canada because most of Canada's wetlands are peatlands. According to Zoltai (1988), the United States system has been designed for use where non-peaty wetlands predominate. Its application in Canada would be difficult, as about 96% of the wetlands in Canada would fall into the category of the Palustrine system, leaving very little room for the differentiation of classes.

3.3 Geographical scale

National level inventories were available for each country. Primary emphasis in this report was placed on securing information at the national level. Information on state or provincial inventories

was obtained for areas which were not covered by national inventories. One multinational review was used to obtain national level information on Mexico's internationally important wetland sites.

Most of the information for the United States was synthesised in the National Water Summary on Wetland Resources (Fretwell et al 1996). This document summarises existing information from the NWI and provides new or complimentary data which were published up until 1996. A national wetland map of the United States was published in 1990 by the USFWS (USFWS 1990).

In Canada, the Canadian Energy Mines and Resources (1986b) published a map of wetland ecoregions and their distribution. The sheer number of wetlands made it virtually impossible to discretely map Canadian wetlands, especially since a vast majority are too small to plot on standard maps (1: 7 500 000). Therefore, wetland regions were mapped based on percentage of wetland coverage. The lack of a detailed site inventory required compilation of information from various regional databases. An emphasis on using databases with at least provincial or multi-provincial coverage was necessary given the great amount of available information. Numerous smaller sub-provincial inventories exist across Canada.

Wetland inventories of Mexico are poor. Only the northwest coastal region has been adequately covered. A national wetland map (published by Conservation International and SEDESOL – now called SEMARNAP) illustrates the location and distribution of Mexico's important wetlands but does not provide detailed information.

In summary, a standard national wetland inventory is only available for the United States. Canadian wetlands regions have been mapped on a percentage basis but a standard national inventory has yet to be produced. Provincial inventories have been completed for most provinces. Inventories of Mexican wetlands consist of an overview of priority wetland sites identified by Scott and Carbonell (1986) and Cervantes & Abarca (1996), and a map sponsored by Conservation International which delineates wetlands but does not provide any associated data.

3.4 Inventory methods

3.4.1 General wetland inventories

In general, national wetland inventories rely on either aerial photographs as the basis for interpreting wetland type and extent and\or depend on soil maps. The latter method often involves ground truth surveys to verify interpreted data. Information can be geo-referenced and stored in large electronic data sets. Efforts are underway to completely digitise wetland maps in the United States and add geo-referenced material, all of which can be accessed through the World Wide Web.

3.4.2 Important wetland site inventories

Identifying important wetlands is largely a function of photo-interpretation and mapping. Site inventories generally secure information on a wide range of issues including size, type, land use, land tenure, biodiveristy, conservation status and threats. Similar methods are employed in Canada, particularly at the provincial level where most of the effort is focused on determining baseline information on wetlands. Some inventories, such as a major mapping project completed for southern Ontario by the Ontario Ministry of Natural Resources, relied heavily on ground truthing as a means of mapping thousands of wetlands and determining their classification (Ontario Ministry of Natural Resources 1984).

Compiling data for the *Directory of Neotropical Wetlands* required national expertise to coordinate the gathering and synthesis of information on a range of issues including wetland size, biological importance, status, threats, conservation, and ownership.

3.4.3 Wetland type inventories

Inventory methods are similar to those obtained for important wetland sites. Wetland type inventories focus on specific wetland habitats. In tropical regions, mangroves, coral reefs and swamp forests are the focus of wetland type inventories. Often these wetland types provide economically important resources (eg peat, timber, fish) or services (eg flood control, fish nurseries, filtration) to society. Peatland studies were often based on soil maps.

3.4.4 Other inventories

Many natural resource inventories are carried out in a similar fashion to those completed for wetlands. Soil inventories are a common source of information on wetlands. The presence of certain soil types are indicative of wetlands and can be easily mapped and verified. Forest inventories also provide valuable information although only recently has it been possible to more accurately differentiate between flooded and dry forest habitats. Many forested wetlands such as black spruce and tamarack swamps, mangrove and some bottomland hardwoods are easily identified and mapped. Inventories of riparian habitat also provide data on wetland areas.

3.5 Extent and adequacy of wetland inventories

Detailed inventories of wetlands exist for both the United States and Canada and provide fairly accurate data on general wetland extent. Specific state and provincial inventories also exist for Canada and the United States. Very little information exists for Mexico.

North American wetland inventories tend to provide a broad overview by state or province. Information on specific sites, however, is limited due largely to the huge number of wetlands. At a scale of 1:24 000 and 1:63 360, wetland maps of the United States provide extensive coverage for every state and territory. This information is extremely useful for monitoring trends in wetland loss and gain. The NWI provides information on extent and type but does not provide the level of detail found in the *Directory of Neotropical Wetlands*. Digitising this information and adding geo-referenced material will make the NWI an extremely powerful tool for analysing changes to wetlands throughout the United States. The NWI is a good source of information on specific wetland types, their extent and distribution.

Developed by the NWWG, the Canadian approach to a national wetland inventory identifies units containing similar wetlands based on shared morphological characteristics. By using this system it is impossible to monitor changes to individual wetlands. Instead, we are presented with regions defined by percentages of wetlands per unit area. The NWWG wetland classification system is at odds with the more focused approach of the NWI. It is therefore necessary to turn to provincial and regional wetland inventories which in many cases attempt to identify and classify discrete wetlands. Unfortunately, many of the inventories employ unique methods for determining wetlands and are therefore difficult to compare. In some cases it is like comparing apples to oranges. A standard national approach to identifying and classifying wetlands would provide a basis for future monitoring. However, given the tremendous number of wetlands in northern Canada alone, the feasibility of this sort of inventory may not be possible given the limited

available resources. Individual provincial wetland inventories may be useful if the same methodologies are adhered to over time.

Wetland type inventories provide excellent coverage for peatlands in Canada and good coverage for coral reefs in the United States. During the report preparation, no information was obtained on the mangrove extent in the United States and limited information for Mexico. Information on rice growing areas, reservoirs and other man made wetlands is incorporated into NWI state reports. This information was not readily available for Canada and Mexico, although a list of reservoirs was reviewed for Mexico but lacked any information on potential wetland extent.

Wetland inventories did not include all wetlands as defined by Ramsar. In particular, shallow coastal waters are not included in any of the material provided. Nor is much attention given to riparian areas. Finally, very little information was obtained on human made wetlands despite knowledge of their existence. Rice farms, aquaculture pools, reservoirs and water impoundments, irrigated lands, and waste water treatment facilities may contribute significantly to wetland creation in North America, particularly in the United States. However, it is unlikely that these areas will reverse the general trend in wetland loss at the national or state level.

3.6 Extent and adequacy of updating activities

Wetland inventories have been periodically updated throughout the past three decades. This includes identifying new wetlands, enhancing information on wetlands for which data was incomplete, and re-assessing old inventories to determine if changes have occurred. The latter provides vital information for analysing trends in wetland loss and creation. A majority of the wetland inventories identified as part of this study provide sufficient information to serve as the basis for monitoring wetland loss, particularly inventories which delineate wetlands using standard or generally accepted classification systems.

Trend analysis for at least one-third of North America is possible due in large part to a significant investment by the United States government over the last three decades to complete a national wetland inventory. Even more importantly, information on the original extent of U.S. wetlands before Europeans settled across the country was recently completed (Dahl 1990). This provides a unique opportunity to analyse trends since the 1780s. In Canada, several long-term datasets allow for analysis particularly in agricultural areas such as southern Ontario (Snell 1987), the Maritimes (Hanson & Calkins 1996, parts of the prairie region and the lower Fraser River valley (see Appendix A for a list of selected wetland inventory databases). In Mexico a recent effort to re-evaluate wetlands of national priority was recently completed and may provide useful data for future trend analysis.

The following summarises information on the extent and adequacy of updating activities as they relate to each of the four wetland inventory categories.

3.6.1 General wetland inventories

The United States government published a report entitled *Wetlands: Losses in the United States, 1780s to 1980s* (Dahl 1990). To obtain these estimates, a ‘picture’ of wetland extent in the 1700s was developed based on current and historical land use information data. Trends in wetland loss were obtained by comparing the difference between the historical and current data sets. This information is provided in Appendix C. Efforts to update wetland information in Canada have been completed for discrete and generally populated areas of Canada. This information is neither

uniform nor was it collected with a common set of objectives in mind. Comparing data from one region to another is practically impossible given the variation in data collection techniques. In some cases, inventories were primarily used to identify key waterfowl areas while others concentrated on potential agricultural lands or areas for natural resource extraction. A general wetland inventory for Mexico has yet to be completed.

3.6.2 Important wetland site inventories

Comprehensive inventories of important wetland sites in the United States and Canada were not found. In the United States, the NWI supersedes this need. In Canada, the immense number of wetlands makes identifying internationally important sites nearly impossible. Gillespie et al (1991) published an overview of existing Canadian Ramsar sites which contains good information on location, size, land tenure, designations and accessibility. However, new sites have since been nominated and the existing sites represent a fraction of the potential existing international sites. The *Directory of Neotropical Wetlands* (Scott & Carbonell 1986) was the first inventory of its kind to systematically identify wetlands of international importance throughout the region. Since its release in 1986, no new directories have been completed to improve and or augment information on Mexican wetlands except for a site profile of priority wetland sites identified by Cervantes & Abarca (1996) based on earlier work of a wetlands coalition. Wetlands of international importance to migratory birds were mapped along Mexico's coast but little if any detailed habitat information is available (RIG Morrison, CWS, pers comm 1999). A recent attempt to identify wetlands of national importance was completed by SEMARNAP (H Berlanga, SEMARNAP, pers comm 1999) and may provide useful information for trend analyses.

3.6.3 Wetland type inventories

Information on activities to update wetland type inventories is sparse. Peatlands, mangrove, swamp forests and cranberry bogs are potential habitat types for which temporal information exists and may be used to obtain wetland loss information. In addition, the extent of newly constructed aquaculture ponds and rice fields may be recorded but represents an almost negligible percentage in terms of total wetland extent for each country. However, at some state levels, the percentage may be significant.

3.6.4 Other inventories

Soil, forest, water resources, and even topographic mapping initiatives all provide information that may be periodically updated. Soil maps can identify changes to water content and may indicate areas which have been drained or altered. Forestry maps provide an inventory of timber resources and, once mapped, can be used to monitor change in forested wetland areas. Topographic maps identify wetlands and are constantly updated. However, these maps were shown to significantly underestimate wetland extent (C. Rubec, Canadian Wildlife Service, pers comm 1999). Wetland identification may vary depending on the interpreter, season and even quality of aerial photos.

4 Use of inventory information to assess the status of wetlands

4.1 Extent and distribution

The quality of information on wetland extent varies significantly amongst the three countries. The NWI provides an unparalleled effort to inventory wetlands in the United States. The results provide a fairly accurate picture of wetland extent by state and territory. Indeed, information on wetland extent by state and territory before European settlement began has also been documented. In Canada, a national effort to inventory wetlands was completed by the Canadian Energy, Mines and Resources (1986a,b) and resulted in a map of wetland 'ecoregions' with associated percentage of wetlands. An inventory of Mexican wetlands relies heavily on important site information (Conservation International et al 1992, Cervantes & Abarca 1996). Wetland distribution maps exist for each country and a summary of these is included in this section.

4.1.1 General wetland inventories

Table 3 summarises information on wetland extent in Canada (NWWG 1988) and the United States (Dahl 1990). A steady decline in wetland extent is observed for conterminous United States. An increase in wetland extent in Canada is likely a result of improved data interpretation. Mexico has not yet completed a national wetland inventory despite the publication of a national wetland distribution map.

Table 3 Wetland extent (ha) in the United States and Canada based on the results of national wetland inventory information

Country	Wetland extent (ha) (1780s)	Wetland extent (ha) (1980s)	Wetland extent (ha) (1985)	Wetland extent (ha) (1988)	Wetland extent (ha) >1988
United States (conterminous only)	89 488 127 [a]	42 238 851 [a]	41 366 092 [b]	-	40 900 000 [b]
United States (Includes Alaska and Territories)	158 389 525 [a]	111 056 479 [a]	-	-	-
Canada	-	-	-	127 199 000 [c]	150 000 000 [d]

a published Dahl (1990)

b USFWS (1998)

c published NWWG (1988)

d approximate number based on recent data indicating total wetland extent in Canada may be as much as 150 000 000 ha based on information indicating increase in peatland area (Polestar Geomatics unpubl.)

4.1.2 Internationally important wetland sites

Although internationally important sites include specific wetlands of importance to wildlife, these inventories have not been included in this report since they only provide partial coverage of the total number of sites. Important inventories include the Ramsar site databases and, for Mexico, wetlands of international importance identified as part of the *Directory of Neotropical Wetlands* (Scott & Carbonell 1986). It is interesting to note that as much as one-tenth of Canada's wetlands have been designated as Ramsar sites (table 4).

Table 4 Number of sites and extent included in national wetland inventories of important sites.

Country	Ramsar sites [a]		Directory of Neotropical Wetlands [b]		Priority Mexican wetland sites [c]	
	Number	Extent (ha)	Number	Extent (ha)	Number	Extent (ha)
Canada	35	13 038 408	-	-	-	-
Mexico	6	1 095 414	40	3 374 900	32	3 064 977
United States	15	1 163 690	-	-	-	-

a List of wetlands of international importance designated under Ramsar, 04/98 (Ramsar Bureau 1998a)

b Scott and Carbonell (1986)

c Cervantes & Abarca (1996)

4.1.3 Wetland type inventories

Wetland type inventories of peatlands, forested wetlands (including mangroves), coral reefs, sea grass beds and several others have been completed for various regions yet very little standardised data are available. Table 5 illustrates the relative amounts of wetland types in the conterminous United States.

Table 5 Extent for selected wetland categories in conterminous U.S. (from USFWS 1998)

Wetland	Extent (ha)
Estuarine (includes subtidal area)	9 355 421
Palustrine*	38 773 693
Lacustrine (not including Great Lakes)	8 256 715
Riverine	2 237 458
Total	**58 623 287**

Palustrine wetlands include forested swamps and flood plains which alone occupy an area of 19 398 543 ha in conterminous United States.

Figures for total wetland extent differ between table 3 and table 5 and may be explained by the inclusion of deepwater habitat for lacustrine, riverine wetlands and subtidal estuarine areas. The figure of 40 900 000 ha is generally considered to be accurate.

Coral reefs

The extent of coral reefs in North America is provided for the United States. Data on coral reef extent for Mexico were not available during the compilation of this report. Delineating coral reefs is difficult and varies amongst inventories. Data included in table 6 do not account for coral reefs to the north of the Florida Keys and a series of patch reefs in the Upper and Lower Keys. In addition, coral reefs extending beyond the U.S. 200 nautical miles exclusive economic zone in the mid-Pacific were not included.

Table 6 Extent of Coral Reefs in North America – United States (NOAA 1998)

Region	0–3 nm (00ha)	3–200 nm (00ha)	Total (00ha)
U.S. Virgin Islands	200	na	200
Puerto Rico	500	na	500
Florida Keys	143	182	325

Texas\Louisiana	0	2	2
American Samoa	271	25	296
Guam	69	110	179
Main Hawaiian Islands	1 655	880	2 535
Northwestern Hawaiian Islands	2 430	9 124	11 554
Northern Mariana Islands	45	534	579
Johnston	130	75	205
Howland	5	0	5
Baker	10	0	10
Jarvis	8	0	8
Palmyra	396	4	400
Kingman Reef	39	10	49
Wake	32	0	32
Total	**5 933**	**10 946**	**16 879**

* nm: nautical miles

According to the data presented in table 6, the area of coral reefs within U.S. jurisdiction (1 687 900 ha) represents a fraction of the total extent of coral reefs worldwide (61 700 000 ha).

The extent of coral reefs in Mexico was not determined. Significant areas exist in the Yucatan, especially along Mexico's border with Belize.

Peatlands

A peatland is a wetland in which extensive organic material has accumulated (NWWG 1988). Detailed information was readily accessible for peatlands in Canada. Information was also available on peatlands in the United States, but with less detail on the extent of peatlands by state or territory. More time is required to secure data on United States peatlands. Table 7 provides a summary overview of peatland extent in North America.

Table 7 Peatland extent in North America

Country	Extent (ha)
Canada (NWWG 1988)	111 327 000
Mexico (1)	1 000 000
United States (2)	61 100 000
Total	**173 500 000**

(1) data from Farnham (1980)

(2) data from Lappalainen (1996)

NWWG (1988) estimates that peatlands cover 111 327 000 ha of Canada's land and freshwater area (close to 12% of the nation's surface area) (table 8). This comprises approximately 90% of the wetlands in Canada (Keys 1992). A recent study completed by Tarnocai et al (1995) estimates that Canadian peatlands occupy an area of 122 383 400 ha, a slight increase in the total amount estimated by NWWG (1988). A distribution map of peatlands is currently under production (Tarnocai & Labelle, in development). Combined, North America has 40% of the world's peatlands.

Table 8 Extent of Canadian peatlands

Province or Territory	Peatland (ha x 1000)	% of area of Province or Territory	Wetland (ha x 1000)	% of area of Province or Territory
Alberta	12 673	20	13 704	21
British Colombia	1289	1	3120	3
Manitoba	20 664	38	22 470	41
New Brunswick	120	2	544	8
Newfoundland	6429	17	6792	18
Northwest Territories	25 111	8	27 794	9
Nova Scotia	158	3	177	3
Ontario	22 555	25	29 241	33
Prince Edward Island	8	1	9	1
Quebec	11 713	9	12 151	9
Saskatchewan	9309	16	9687	17
Yukon Territory	1298	3	1510	3
Canada	**111 327**	**12**	**127 199**	**14**

Source modified from NWWG (1988)

Mangroves

Mangroves are restricted to tropical coastal zones. Mangrove forests are found throughout southern Florida and the Keys. Larger expanses of mangrove occur along both coasts of Mexico, particularly along the Yucatan coast. Compared with the 660 000 ha estimated by (Blasco 1988), the extent of mangroves in the United States is minimal. Only Brazil has larger expanses of mangrove forest in the Americas. The NWI does not delineate mangrove forests which are included with shrubs and forests under Cowardin's classification system. A complete inventory of Mexico's mangroves was not available. Various estimates based on coastal resource inventories have been completed and provide a basis for estimating current mangrove extent. Data are believed to be available and future efforts to secure this information are needed.

Freshwater forested (palustrine) wetlands

A national inventory of freshwater forested wetlands has not been undertaken. However, as part of the NWI, it is possible to determine the extent and location of these wetland habitat types. In the United States, there are currently 18 878 531 ha of forested wetlands (Frayer 1991). Estimates for Canada and Mexico were not available. More data are required.

Human-made wetlands

Inventories of rice fields have been undertaken for some agricultural regions. Data on the total extent of rice fields and other related human-made wetlands was not encountered during this study. This includes reservoirs, aquaculture ponds, irrigated lands and water diversion projects. More data are needed.

Seagrass beds

Seagrass beds occur along coastal areas throughout North America. Very little data on seagrass beds were obtained for this report although Orth et al (1990) provide some data on extent of this vegetation in 10 states which are summarised in table 9.

Table 9 Extent of seagrass beds for select States in the U.S.

State	Extent (ha)
New York	78 100
New Jersey	12 624
Virginia-Maryland	17 353
North Carolina	80 972
Florida – Atlantic coast	2800
Florida – Gulf coast	913 700
Alabama	12 300
Mississippi	2000
Louisiana	4100
Texas	68 500
Total	**1 192 449**

4.1.4 Other inventories

Natural resource inventories provide valuable information on wetland extent in North America. Both Canadian and United States mapping and classification efforts relied on soil maps to identify wetland areas. Many federal agencies, particularly in the United States and Canada (eg NOAA, EPA, USDA Natural Resources Conservation Service, Agriculture Canada, USDA Forest Service, Fisheries Canada), have complete resource inventories which include wetlands. None, however, provide the complete extent and distribution offered by the NWI and NWWG efforts.

4.2 Wetland benefits and values

Many of the inventories analysed provide both quantitative and qualitative information on wetlands values and benefits. Fretwell et al (1996) summarise wetland benefits and values for each state, providing both a general overview as well as specific examples for various activities.

For example:

Arizona – In 1978 more than 46 000 visitors to 3 wetlands in southern Arizona generated more than $US 5 million in tourism revenue or approximately $US 12 370 per acre.

Hawaii – Native Hawaiian communities depended on wetlands for cultivation of Taro and other staple food crops and for coastal fisheries.

Louisiana – Shellfish and finfish revenues from coastal and inland waters estimated at $US 680 million annually, as flood control devices it has been stated that 1 mile of marsh reduces a storm surge by approximately 1 foot.

Michigan – Was one of five states that together produced 75% of the peat harvested in the United States.

Mississippi – Coastal wetlands are important in supporting a $US 50 million commercial and recreational fishery.

New Jersey – More than 3000 acres of cranberry bog were under private management in 1992.

North Dakota – The prairie pothole region extending across most of the state accounts for 50% of the duck crop in North America in an average year.

Oregon – 50% of shellfish depend on wetlands during their life-cycle.

In his report to the North American Wetland Conservation Council–Canada, Keys (1992) found revenues from horticultural peat in 1990 exceeded $US 70 million and provided employment for thousands of residents in rural areas of Canada. The total value of peat products sold annually in Canada now exceeds $US 75–80 million (Keys 1992).

The NWWG (1988) summarised various benefits of wetlands including costs associated with replacing wetland functions (eg fish production, wildlife breeding, nutrient removal), expenditures of recreational users at specific wetland marshes, and the value of the fisheries industry in Canada during a specific year. A summary of the economic benefits of wetlands was costed at $US 4–8 billion annually.

The *Directory of Neotropical Wetlands* (Scott & Carbonell 1986) provides a site profile of wetland benefits which, although general, is useful. Site inventories generally do not provide this level of detail in Canada and the United States.

NOAA's Website identifies several economic benefits of coral reefs. These include data that indicate: visitors spend about $US 1.2 billion annually in the Florida Keys where the reef tract is a primary attraction; coral reefs in Hawaii are central to a $US 700 million marine recreational industry; and the value of reef fisheries off the Florida Keys and Hawaii is estimated at $US 48.4 million and $US20 million, respectively.

4.3 Land tenure and management structure

Land tenure and management issues are addressed in many of the inventories. From a state, provincial or territorial perspective, this information is of minimal use except to identify the agencies who are responsible for their conservation and/or management. Detailed information from national level inventories on the management and responsibilities of federal agencies is provided. For Mexico, there is little information on land tenure and management issues at the national level. Provincial, state and territorial coordinated inventories tend to provide more detailed information on land tenure issues, particularly when these inventories are carried out at the site level. Wetland coverage and available resources to carry out each inventory probably have an influence on the level of detail obtained.

In the United States, the Natural Resources Conservation Service (NRCS) undertakes an inventory of the natural resources on non-federal lands every five years. This provides a 'snap-shot' of resource conditions on all the nation's farms, non-federal forests and grazing lands (except Alaska) – approximately 74% of the land area or 541 million ha. Although it doesn't specify who has ownership of wetlands, it does provide information on land cover/ use in the following categories: crop land, pastureland, rangeland, forest land, rural land, developed land and water areas (NCRS 1994). It also identifies the type of land ownership as well as appropriate conservation practices. Other federal agencies with mapping responsibilities include the USFWS which oversees mapping and inventory of all the nation's wetlands. The USFWS also oversees management of wildlife refuges throughout the United States. Many of these reserves were established to protect wetlands and adjacent habitats.

NOAA deals with coastal wetlands associated with marine resources. The USDA Forest Service, Bureau of Land Management, Department of Defense, and the National Park Service all have responsibility for managing federally owned wetlands in the United States. Section 4.1.2 describes the area protected as Ramsar sites.

In Canada, significant areas of crownland (government owned) are managed by the federal government. A federal policy on wetlands guides land use decisions for most of Canada's crownlands and is administered by Environment Canada. Section 4.1.2 describes areas designated as Ramsar sites. According to this data, 10% of Canada's wetlands are designated Ramsar sites. Territorial governments in northern Canada are now responsible for managing large tracts of wetlands. Nunavit, Canada's newest territory, occupies most of the northern lands in the central and northern Arctic region – an area of extensive tundra wetlands. Canada's national park system protects representative wetlands in every province and territory. Although most of these parks provide strict protection for a variety of habitat types, a significant number of parks were established to protect nationally important wetlands.

Table 10 Status of important wetland sites in Mexico

Inventory name	Number sites	Area (ha)	Completely protected %	Partially protected %
Directory of Neotropical Wetlands	40	3 374 900	12.5 % (5 sites)	2.5% (1 site)
Zonas Humedas Prioritarias	32	3 064 977	34% (11 sites)	na

In Mexico, SEMARNAP is responsible for overseeing the conservation and management of wetlands on federally owned land. Management of wetlands at the state level is relatively new although initiatives are underway in Tabasco and Nayarit (M Cervantes, Wetlands International, pers comm 1999). The *Directory of Neotropical Wetlands* (Scott & Carbonell 1986) lists 40 internationally important sites and provides general information on the protected status of each site. An inventory of priority wetlands in Mexico (Cervantes & Abarca 1996) notes protective status for 11 (34%) sites (table 10).

4.4 Rate and extent of wetland loss and degradation

Several thorough reviews of wetland loss have been published over the last two decades for the United States and parts of Canada. The NWI provides an extremely useful tool for monitoring wetland loss over the short and long-term. Canada's various regional inventories also offer excellent opportunities for monitoring trends in wetland loss and/or degradation. However, a standard format for measuring wetland loss across Canada varies given the different parameters used to establish baseline data on wetlands. Preliminary data from Cervantes & Abarca (1996) provides a figure for wetland loss and degradation in Mexico. Table 11 offers a national perspective on wetland loss and degradation in North America.

Table 11 Loss and degradation of original wetland extent

Country	Original extent (ha)	Current extent (ha)	Loss %
Canada (1)(2)(3)	147 905 810 (pre-European settlement)	127 199 000 (1988)	~14%
Mexico (4)(5)	4 479 975 (since 1800s)	3 318 500 (1993)	~35%
United States – all (6)	158 389 525 (c1780s)	111 056 479 (c1980s)	~30%

1 Data on current extent from NWWG (1988).

2 Data from C. Rubec, pers. comm concerning original extent and % wetland loss.

3 Recent data from Polestar Geomatics (unpubl.) indicate substantial increase in peatland area which may increase current wetland extent in Canada to as much as 150 million ha.

4 Data on wetland extent from Olmsted 1993.

5 Original extent determined based on information on wetland loss from Cervantes & Abarca (1996).

6 Data from Dahl (1990). Original extent determined for NWI. Dates listed as circa 1780s and circa 1980s. Wetland loss at the state level is available.

In her assessment of land use change on and adjacent to wetlands in southern Canada, Lynch-Stewart (1983) concluded that there are significant gaps in available information, making a national overview of wetland conversion difficult to achieve. As a result, numerous examples of wetland conversion are provided but a national perspective is not possible using current available data. Wetland losses are greatest in populated regions of Canada including the Fraser River valley of British Colombia, southern Ontario and Quebec and parts of New Brunswick and Nova Scotia. Conversion rates in the Province of Ontario are some of the highest – exceeding 1 200 000 ha or 70% loss of total wetland area in the most populous region of Canada. Conversion of the prairie pothole wetland region of Alberta, Saskatchewan and Manitoba to grain and forage crops has been extremely aggressive over the past 150 years. Ducks Unlimited manages a mapping meta-database on the wetlands of this region and has access to wetland loss data (Ducks Unlimited 1991).

Wetland loss as a percentage by state varies from 9% for New Hampshire to 91% for California. Wetland loss in the conterminous United States between 1780s and 1980s is 53% or equivalent to 5% of the total land surface area (Dahl 1990).

5 Discussion and conclusion

5.1 Adequacy of information base

Large amounts of information have been gathered from national and sub-national wetland inventories in both Canada and the United States. The United States government maintains and continues to update information through the national wetland inventory. Canadian wetlands have been inventoried but not with the perspective of contributing to a national effort. Canadian inventories have tended to focus provincially, often relying on unique classification systems adapted to meet a province's specific objectives. Although this has occurred in the United States, a national inventory standard was accepted and is being used. This facilitates regional and national level monitoring. Mexico has focused its resources on inventorying nationally and internationally important wetlands. Many wetlands are not considered on this priority list and as a result, a complete picture of the status of wetlands is unavailable. For now, the Mexican government is focusing on priority wetland areas, where it will target its conservation resources.

In most instances, inventories from the United States and Canada provide useful and often quite detailed information that can assist managers, planners and policy analysts to make informed land use decisions.

5.1.1 General wetland inventories

Information from the United States NWI on extent, type and location is stored electronically and information is now geo-referenced to ensure accuracy of data collection. Efforts to fully digitise these data will make them readily available on the World Wide Web. Widespread implementation of the NWI has enabled the United States government to develop a powerful tool for analysing

long-term trends in the status of wetlands (eg Dahl 1990, Dahl & Johnson 1991). Efforts to determine wetland extent during pre-colonial times have helped to establish a benchmark for monitoring wetland loss and/ or change over a 200 year period. This is important for determining appropriate land use treatments to minimise or even reverse the impact of wetland loss and/or change.

The NWWG has developed a different methodology for classifying wetlands. In contrast with the NWI, the NWWG classification system considers the ecological characteristics of a wetland or wetland complex as opposed to its hydrological characteristics. Using this system, the wetlands of Canada have been mapped according to shared characteristics. A map of wetland distribution (on a percentage wetland basis) superimposed on a map of wetland ecoregions enables the user to assess the percentage area of each wetland ecoregion. Although viewed as an important achievement, the NWWG classification system has not been widely used. As a result, many inventories have been carried out throughout Canada and vary enough to make it difficult for data comparison.

5.1.2 Important site inventories

Unlike other regions, comprehensive site inventories of nationally and internationally important wetlands were not available for the United States and Canada. Only Mexico has recently produced several national inventories of wetlands of importance or priority (Scott & Carbonell 1986, Cervantes & Abarca 1996). Interestingly, data on the extent of Mexican wetlands from the *Directory of Neotropical Wetlands* (Scott & Carbonell 1986) are almost the same as data published by Olmsted (1993) in *Wetlands of the World*.

Using data from important site inventories to determine wetland extent is limited. First, the data only partially represent all wetlands. Many wetlands remain unidentified and therefore, the data undervalues the true wetland extent. Second, these inventories tend to be biased towards larger wetlands. Third, they are often selected because of their biodiveristy value.

5.1.3 Wetland type inventories

National wetland type inventories for many wetland types (eg peatlands, swamp forests, estuarine habitat, coral reefs and seagrass beds) have been compiled for North America.

Peatlands have been the most intensively and extensively inventoried. Information gathered from various sources tend to compliment one another although new information suggests that current figures still underestimate the true extent in Canada by as much as 5–10% (C Rubec, CWS, pers comm 1999).

Information on coral reefs is lacking for Mexico. In the United States, the most extensive coral reefs have been inventoried and are being monitored. The figures presented in this report are preliminary and although they provide an overview of coral reef extent, at least for the United States, the data is probably conservative. Methods for determining coral reef extent in the U.S. Virgin Islands and Puerto Rico are lacking and estimates for Hawaii are considered preliminary because coral coverage estimates for much of the northwest region are based on the assumption that existing hard bottom areas contain corals.

Summary information on mangrove extent in North America exists for Mexico and was published in a recent report by Cervantes & Abarca (1996). Although data on mangroves for the United States was not obtained, extent of ‘marine intertidal forested and scrub\shrub’ habitat from Frayer

and Hefner (1991) is assumed to be comprised of mangrove (to what extent was not determined during the compilation of this report).

Although not explicitly inventoried nationally, the extent of freshwater forested wetlands has been determined through the NWI using Cowardin et al's (1979) classification scheme.

In general, inventories of wetland types tend to be more defined in their approach and therefore provide useful information for monitoring. This is particularly true for habitat types which are readily identifiable. Some wetland types are difficult to determine, especially those that may require a knowledge of the hydrology. For example, delineating forested wetlands requires some knowledge of flooding conditions which can in some cases significantly increase a wetland area. Given the temporal nature of floods, aerial photos may not capture this information.

5.1.3 Other inventories

Due to the large amount of information available on wetlands in Canada and the United States, other inventory types were not extensively analysed. In Mexico, however, land use surveys may serve as the basis for undertaking national or sub-national inventories should this be a priority of the government or other interested organisations.

5.1.4 Summary of wetland extent information

Sufficient information exists to provide estimates of wetland extent in Canada and the United States. For Mexico, data estimates are still preliminary. However, there does seem to be general consistency among the published figures. Olmsted's (1993) figure for total wetland extent is presented since other published figures represent a compilation of areas from site inventories which are not considered complete. Data for wetland type habitats at the national level are presented as the best estimates to date. New information is constantly being published and may replace existing data. Information on seagrass beds, coral reefs, mangroves, forested wetlands, and peatlands are presented in table 12.

Table 12 Summary of wetland extent in North America

Inventory	Extent (ha)	Reference	Notes
Peatlands			(table 7)
Canada	111 327 000	NWWG (1988)	More recent estimate of 134 million (Polestar Geomatics 1999)
United States	61 100 000	USDA (1994) and Farnham (1980)	figure taken from table in Lappalainen (1996)
Mexico	1 000 000	Malterer in Lappalainen (1996)	unsubstantiated and may include other wetlands
Forested wetlands			No estimates available for Canada and Mexico
United States	18 878 531	Frayer (1991)	as per classification used by NWI
Coral reefs			(table 6)
United States	1 687 900	NOAA (1998)	no information from U.S. Virgin Islands, Puerto Rico – information includes only coral within U.S. waters
Mangroves			
United States & Mexico	660 000	Blasco (1988)	in report prepared by Flores (1996)
Sea grass			(table 9)
United States	1 192 449	Orth et al (1990)	for Eastern Atlantic and Gulf of Mexico coasts

Ramsar sites			
Canada	13 038 408	Ramsar (1998a)	
Mexico	1 095 414	Ramsar (1998a)	
United States	1 613 690	Ramsar (1998a)	
Directory of Neotropical Wetlands			(table 4)
Mexico	3 374 900	Scott & Carbonell (1986)	for 40 important sites
National Wetland Inventories			(table 3)
Canada	127 199 000	NWWG (1988)	new data indicate may increase to 150 million ha
United States	111 056 479	Dahl (1990)	Includes U.S., Alaska and Territories. NWI information also available at State level.
National Overview			
Mexico	3 318 500	Olmsted (1993)	in *Wetlands of the World* (Olmsted 1993)

5.2 Methodologies

Methodologies for inventorying wetlands within North America vary. The United States has adopted Cowardin et al's system since the early 1980s and it has become a standard of federal and state agencies throughout the country. One of its main strengths is its wide scale acceptance and implementation. The standards adopted facilitate analysis of general trends by wetland type (class) or geographic region (state). Digitisation of the information to improve electronic access will facilitate information use. Currently, information contained in the NWI is basic and does not provide comprehensive data on biophysical and socio-economical parameters which influence wetland form and function.

A system for classifying Canadian wetlands was presented by the NWWG in 1998 and used to complete a general inventory of Canada's wetlands. However, the system has not been widely adopted at the regional level and several other systems have been implemented to suit the objectives of specific inventories. Compilation of data from the many and varied inventory sources is time consuming and presents a challenge. It was concluded that future efforts to compile and synthesise existing inventories should not be undertaken and data sources for particular regions or wetland types be used as the basis for regional information (Polestar Geomatics 1995). Lack of a national inventory with a standard classification system makes it virtually impossible to monitor wetlands at the ecosystem level except in those areas which have developed their own inventories. Advances in remote sensing technologies combined with a wealth of information on wetlands in Canada may facilitate the development of a national database. However, there are no known plans to undertake this task.

In Mexico, a national classification system based on Cowardin et al's work was presented by Cervantes & Abarca (1996) but has not been implemented. Development of a national classification system for Mexico would help to establish a useful database for monitoring wetlands.

5.3 Use of inventory information to identify sites for monitoring trends in wetland condition

Current information from wetland inventories is being used to monitor wetland trends in the United States, Canada, and to some degree in Mexico.

5.3.1 General wetland inventories

The NWI has identified 'most' wetland sites in the United States. However, NWI databases contain limited information on the status of each wetland since it focuses mainly on wetland classification and extent. For example, the loss of wetlands at any given site may be recorded, but data indicating the cause may not. However, some information on land use and other features can be added as 'modifiers' to the current classification system, thus providing additional detail on wetland status. Geo-referenced data sets may also facilitate a greater understanding of changes to any given site.

Regional inventories in Canada may provide useful information for identifying wetlands for monitoring trends. Examples include extensive datasets managed by Ducks Unlimited–Canada (Ducks Unlimited 1991) for the prairie pothole region and databases held by the Ontario Ministry of Natural Resources with information on 2400 sites in southern Ontario (OMNR 1984). The latter data set contains maps and extensive information on each wetland. Other sites in the Pacific and Northern regions of Canada are likely to contain valuable information for monitoring trends.

5.3.2 Important site inventories

In Mexico, several important site inventories have been carried out since 1986. These include detailed inventories of priority wetland sites for conservation throughout Mexico. The broad geographic representation and the availability of information on these sites make this data set useful for considering as the basis for identifying sites for monitoring trends in wetland condition.

Databases with information from inventories of Ramsar sites should also be considered. Although largely protected in the U.S. and Canada, these sites are still under significant pressure in Mexico and elsewhere and may present a more realistic perspective of wetland trends.

5.3.3 Wetland type inventories

Valuable data on wetland types exist and could be used as the basis for monitoring changes to specific wetland habitat types, eg mangroves or coral reefs. However, current inventories of these wetland types provide limited information. Peatlands may prove to be excellent sites for monitoring wetlands and their effect on carbon sequestration. As major carbon sinks, monitoring changes in these habitats may help to understand their role in regulating green house gases. Extensive databases on wetland information exist in Canada and the United States and could serve as the basis for identifying areas or regions where more extensive data collection could begin.

5.3.4 Other inventories

Again, extensive information on wetlands in North America already exists for most areas of North America. However, inventories containing information on related issues may compliment data already gathered. For example, information on protected areas could help to build a useful picture of the extent of wetlands protected in a given region.

5.4 Use of inventory information as a baseline for monitoring wetland loss

Inventories provide valuable information for monitoring change. The NWI has been particularly useful from a national and state perspective by securing baseline information necessary to analyse change. In addition, estimates of wetland extent have been documented for each state dating back to the 1780s – a period when wetlands were considered to be relatively unaffected by European

colonisers. Every ten years, the U.S. government has committed to producing a status report on the wetlands of the United States. Data from the NWI provides the basis for these reports. The first publication on wetland trends was released by the USFWS in 1990 (USFWS 1990).

Important site inventories in Mexico have measured wetland extent but mapping efforts are generally lacking. Mapping inventories created by groups like Ducks Unlimited–Mexico and Conservation International have helped to demonstrate the utility of such inventories in conservation and management. Ducks Unlimited's efforts to map areas of particular importance to waterfowl may be useful for monitoring long-term changes.

6 Specific recommendations

6.1 Efforts to promote a standard national wetland classification system in Canada and Mexico would facilitate a better understanding of the resource and its status. However, regional efforts are also important and provide a focused approach adapted to the needs and realities of a specific area.

6.2 Many regional inventories in Canada and the United States exist and provide an ideal framework within which to identify a network of sites for monitoring change. Included in a selection of sites are Ramsar sites. These internationally recognised sites could serve as nodes for wetland monitoring efforts across the continent.

6.3 In order to understand national trends, greater emphasis on providing a tool for disseminating results from wetland inventories is needed. This is particularly the case for Canada where tens of regional inventories have generated excellent data but the data are generally inaccessible to the public.

6.4 A continental project to map North America's wetlands would help to provide a unique multinational perspective on the conservation of these highly productive ecosystems. Because they are dominated by water, and water is very much a shared commodity between the three countries, wetlands offer an excellent vehicle for fostering cooperation on wetland and water issues.

6.5 Methods of easily assessing the economic value of a wetland needs to be developed and data should be included in inventory projects underway. These data are critical for building an awareness of wetland value. Very little information is currently available or is, at best, anecdotal.

6.6 Training to develop the capacity to manage wetlands at the local level is critical. Local communities need to be actively engaged in monitoring and inventorying wetlands. Through their participation greater stakeholder involvement will likely occur. Local communities are also a source of information on wetlands which has been gathered over generations. This knowledge base is not available through standard methods of gathering information (eg aerial photo interpretation). Empowering local communities to become custodians of 'their' data is key to ensuring local community involvement in wetland conservation. Again, the World Wide Web may facilitate this, especially in Canada and the United States.

6.7 'Hot spot', 'vital', or 'representative' wetlands need to be identified based not only on their importance for birds but all biodiversity (including fish, reptiles, amphibians). In the past, many important wetlands were identified as priority areas based on their significance as staging, breeding or feeding habitats for birds. 'Hot spot' wetlands could include a representative wetland for each geographical region or wetland ecoregion. This method of identifying 'vital' wetlands could be used to strategically designate Ramsar sites so that they represent the world's variety of wetland ecosystems. Wetlands of tremendous importance to humans both through the services and functions they provide as well as their cultural value, should be incorporated into this 'hot spot' approach.

6.8 Either the Cowardin, NWWG or Ramsar model provides a method for classifying wetlands. Each was developed to suit a particular purpose. Efforts to develop a national

standard to classify and inventory Mexican wetlands would help establish the basis for a national wetland monitoring program. Mexico is a unique position to develop an appropriate classification system based on the strengths of existing models.

6.9 Governments need to work closely with and support the NGO sector in developing local capacity to access and use wetland inventory information. Ideally, local groups should be involved in monitoring programs. The World Wide Web may help to facilitate this issue.

6.11 Current information on the extent of human made wetlands is not readily available. These areas can and do have a large impact on wildlife, human communities, climate and a range of related issues. A knowledge of how they impact on humans and natural resources would be useful for habitat managers.

6.12 Peatlands, and potentially Ramsar sites on peatlands, may be extremely useful areas for establishing climate change monitoring stations. Peatlands are recognised as important carbon sinks but their potential effect on climate is still unknown. Given predicted global climate warming in the rich tundra peatland regions of northern North America, greater effort to understand the role of peatlands is vital to our understanding of changes which may affect current peatland management and conservation practices.

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Appendix A List of Select Regional Inventories

Canada

1. Great Lakes Wetlands Conservation Action Plan 1994–2000, 1995, Ontario Ministry of Natural Resources.
2. Land Use Change on Wetlands in Southern Ontario, 1983, Environment Canada.
3. Location, Amount, Cover Type and Productivity of Wetlands of Potential Interest to Ducks Unlimited in parts of Northwestern Ontario, 1985, Ducks Unlimited.
4. National Role in Providing Fish Habitat in Canada, 1996, R Bailey.
5. Geographic Information System Wetland Database, 1995, Nova Scotia Department of Natural Resources.
6. Environmental Atlas of St Lawrence, Wetlands: Habitats on the Edge of Land and Water, 1991, Environment Canada.
7. Soil Landscapes of Canada, 1996, Agriculture Canada.
8. Ontario Wetland Map Summary, 1983, Federation of Ontario Naturalists.
9. Wetlands of the St. Lawrence River Region: 1950–1978, 1985, Environment Canada.
10. Natural Heritage Information Centre, 1997, OMNR.
11. Sensitive Ecosystems Inventory of East Vancouver Island and Gulf Islands, 1997, BC Ministry of Environment, Lands and Parks.
12. Annotated list of large prairie wetlands, 1967, Canadian Wildlife Service.
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14. Fraser Lowland Wetland Inventory, 1989, Canadian Wildlife Service.
15. Wetlands of the Maritime Provinces. 1996, Canadian Wildlife Service.
16. Distribution of Wetlands in the St Lawrence Plain, 1988, Quebec Soil Survey Unit.
17. The Peatlands Areas of Nova Scotia, 1988, Nova Scotia Department of Mines and Energy.
18. Peat Resources in Newfoundland, 1993, Peat Conference Proceedings.
19. Prince Edward Island Freshwater Wetlands Inventory, 1981, CWS, Atlantic Region.
20. An Investigation of the Peat resources of New Brunswick, 1974, NB Department of Natural Resources and Energy.
21. Peatlands of Alberta, 1992, BJ Nicholson, LA Halsey & DH Vitt.
22. Agricultural Use and Extent of British Colombia Wetlands, 1989, Agriculture Canada.

United States of America

23. Alaska Wetlands and Hydrography, 1996, Alaska Wetlands GATF Project.
24. Eastern South Dakota Wetlands, 1997, South Dakota State University and USFWS.

25. Florida Wetlands Status and Trends: 1970s to 1980s, 1991, USFWS.
26. Mid-Atlantic Wetlands: A Disappearing Natural Treasure, 1987, USFWS and US EPA.
27. Pennsylvania's Wetlands: Current Status and Recent Trends, 1990, USFWS.
28. Status of Alaska's Wetlands, 1994, USFWS.
29. Texas Coastal Wetlands: Status, Trends, Mid-1950s to Early 1990s, 1997, USFWS.
30. West Virginia's Wetlands: Uncommon Valuable Wildlands, 1996, USFWS.
31. Wetlands of the California Central Valley: Status and Trends 1939 to mid-1980s, 1989, USFWS.
32. Wetlands of Maryland, 1995, USFWS.
33. Wetlands Resources of Illinois: An Analysis and Atlas, 1994, Illinois Natural History Survey.

(and many others from each state)

Appendix B Cowardin's Classification System of Wetlands and Deepwater Habitats

Classification hierarchy of wetlands and deepwater habitats, showing Systems, Subsystems, and Classes. The Palustrine System does not include deepwater habitats.

System	Subsystem	Class
Marine	Subtidal	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Reef
	Intertidal	Aquatic Bed
		Reef
		Rocky Shore
		Unconsolidated Shore
Estuarine	Subtidal	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Reef
	Intertidal	Aquatic Bed
		Reef
		Streambed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
		Scrub-Shrub Wetland
		Forested Wetland
	Tidal	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		StreamBed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland

Appendix B continued

Riverine	Lower Perennial	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
	Upper Perennial	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
	Intermittent	Streambed
Lacustrine	Limnetic	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
	Littoral	Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Rocky Shore
		Unconsolidated Shore
		Emergent Wetland
Palustrine		Rock Bottom
		Unconsolidated Bottom
		Aquatic Bed
		Unconsolidated Shore
		Moss-Lichen Wetland
		Emergent Wetland
		Scrub-Shrub Wetland
		Forested Wetland

Appendix C Wetland Losses in the United States: 1780s to 1980s (Dahl 1990)

State	Estimates of Original Wetlands Circa 1780s	Estimates of Existing Wetlands Circa 1980s	% Wetland Lost
AL	7 567 600	3 783 800	50%
AZ	931 000	600 000	36%
AR	9 848 600	2 763 600	72%
CA	5 000 000	454 000	91%
CO	2 000 000	1 000 000	50%
CT	670 000	172 500	74%
DE	479 785	223 000	54%
FL	20 325 013	11 038 300	46%
GA	6 843 200	5 298 200	23%
ID	877 000	385 700	56%
IL	8 212 000	1 254 500	85%
IN	5 600 000	750 633	87%
IA	4 000 000	421 900	89%
KS	841 000	435 400	48%
KY	1 566 000	300 000	81%
LA	16 194 500	8 784 200	46%
ME	6 460 000	5 199 200	20%
MD	1 650 000	440 000	73%
MA	818 000	588 486	28%
MI	11 200 000	5 583 400	50%
MN	15 070 000	8 700 000	42%
MS	9 872 000	4 067 000	59%
MO	4 844 000	643 000	87%
MT	1 147 000	840 300	27%
NE	2 910 500	1 905 500	35%
NV	487 350	236 350	52%
NH	220 000	200 000	9%
NJ	1 500 000	915 960	39%
NM	720 000	481 900	33%
NY	2 562 000	1 025 000	60%
NC	11 089 500	5 689 500	49%
ND	4 927 500	2 490 000	49%
OH	5 000 000	482 800	90%
OK	2 842 600	949 700	67%
OR	2 262 000	1 393 900	38%

Appendix C continued

PA	1 127 000	499 014	56%
RI	102 690	65 154	37%
SC	6 414 000	4 659 000	27%
SD	2 735 100	1 780 000	35%
TN	1 937 000	787 000	59%
TX	15 999 700	7 612 412	52%
UT	802 000	588 000	30%
VT	341 000	220 000	35%
VA	1 849 000	1 074 613	42%
WA	1 350 000	938 000	31%
WV	134 000	102 000	24%
WI	9 800 000	5 331 392	46%
WY	2 000 000	1 250 000	38%
SUBTOTAL (Contermin ous U.S)	221 129 638	104 374 314	53%
Alaska	170 200 000	170 000 000	0.1%
Hawaii	58 800	51 800	12%
TOTAL U.S	391 388 438	274 426 114	30%

1 Wetland distribution and changes vary dramatically within states dependent on both geographical and/or land use patterns